THE 2.5 GeV BOOSTER SYNCHROTRON FOR THE SOLEIL PROJECT

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Abstract

The injection system of the Synchrotron Light Source SOLEIL is composed of a 100 MeV electron Linac preacceleraror followed by a 2.5 GeV fast cycling booster synchrotron. Different FODO structures were studied for the booster lattice. A four period FODO structure with missing magnet was selected. This structure allows for a good injection process with a large dynamic aperture at 100 MeV and a small transverse beam size at full energy. The low beam emittance and the 12 Hz cycling frequency ensure a storage ring filing rate of less then 2 minutes for the different operating modes.

1 INTRODUCTION

Two structure types was studied who achieved the booster performances. The proposal, presented in the following, and a dispersive lattice. From an optical point of view, these later gives similar results, but the constraint on the thin septum was strong and this structure was not retained.

2 LATTICE OF THE BOOSTER

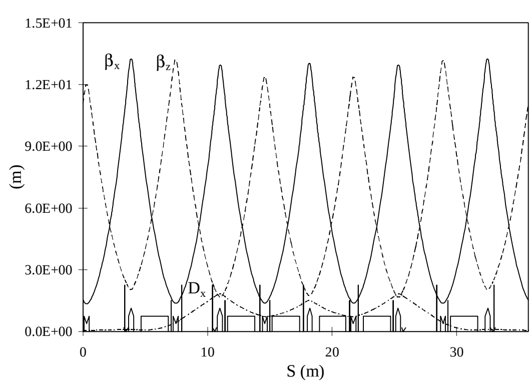

Figure 1 : Optical functions and dispersion of the booster

The cells of the booster is a FODO structure with missing magnet [1]. We adopt a configuration of 4 periods composed of 10 cells with 4 without magnet. Injection and extraction scheme will be inserted in the free drift sections. The number of FODO cells and the betatron phase advance per cell have been chosen to cancel the dispersion function in the drift section with only two quadrupoles families. In addition, we have also two families of sextupoles to correct the chromaticity at injection. The optical function are shown in the figure 1 and the main parameters are resumed in table 1.

Final energy	2.5 GeV
Injection energy	0.1 GeV
RF Frequency	352.202 MHz
Circumference	143 m
Period	4
Cycling frequency	12 Hz
Horizontal emittance	2.7 10^{-7} π.m.rad
Energy spread	7.3 10^{-4}
Energy losses by turn	417 keV
Betatron tunes (ν_x , ν_z)	6.32 ; 5.31
Momentum compaction	3.35 10^{-2}
Natural chromaticities (ξ_x , ξ_z)	-1.31, -1.35
Damping times (τ_x , τ_z , τ_s)	6.3, 5.7, 2.7 ms
Bending magnet angle	15 °
Quadrupole strength (K_f , K_d)	1.20, -1.05 m^{-2}

Table 1 : Main parameters of the booster

3 INJECTION AND EXTRACTION

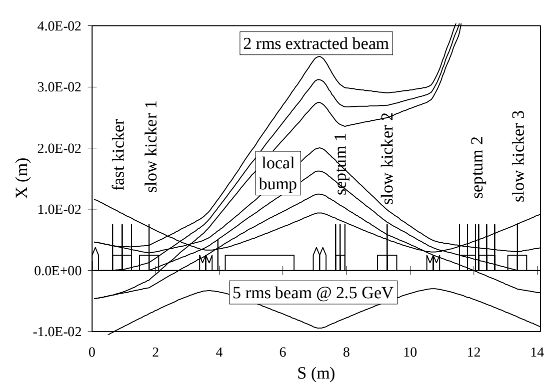

Figure 2 : Extraction scheme

The 100 MeV beam from the linac is injected on the axis with a 131 mrad septum and a fast kicker of 12 mrad [4]. After a local closed orbit bump set with 3 low kickers, the circulating beam is extracted in one turn using a fast kicker and two pulsed septum magnet. The extraction scheme is presented in the figure 2 and the different element characteristics are resumed in table 2.

Fast Kicker	1
Length	0.6 m
Nominal field @ 2.5 GeV	0.02086 T
Nominal deviation	0.00150 rad
Slow Kicker	3
Length	0.6 m
Nominal field @ 2.5 GeV	0.04587 T
Nominal deviation	0.0033 rad
Eddy Current Septum (Septum 1)	1
Length	0.3 m
Nominal Field @ 2.5 GeV	0.23004 T
Nominal deviation	0.0083 rad
Septum thickness	0.003 m
Thin Septum (Septum 2)	1
Length	1.0 m
Nominal Field @ 2.5 GeV	0.91740 T
Nominal deviation	0.11 rad
Septum thickness	0.012 m

Table 2 : Extraction characteristics.

4 CLOSED ORBIT CORRECTION

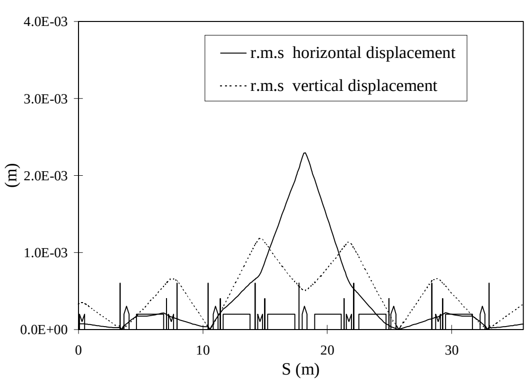

Figure 2 : One standard deviation of the corrected CO.

To correct the closed orbit (CO) at injection, we have 16 beam position monitors (BPM) and 32 dipolar correctors (16 per plane). The r.m.s corrector strength and the r.m.s corrected CO are determined by an analytical method [2,3]. We present in the figure 3 the corrected CO for one standard deviation with the defaults resume in the table 3. The maximum correctors strength, for one standard deviation, is of 0.31 mrad in the horizontal plane and is of 0.21 mrad in the vertical plane.

Dipole

r.m.s $\Delta B/B$	$0.77\ 10^{-03}$
r.m.s ΔL	$5\ 10^{-04}$ m
r.m.s Δx	$2\ 10^{-04}$ m
r.m.s Δz	$2\ 10^{-04}$ m
r.m.s Δs	$1\ 10^{-03}$ m
r.m.s $\Delta\phi_s$	$5\ 10^{-04}$ rad

Quadrupole

r.m.s $\Delta Gl/Gl$	$5\ 10^{-03}$
r.m.s Δx	$2\ 10^{-04}$ m
r.m.s Δz	$2\ 10^{-04}$ m

Table 3 : One standard deviation field error and misalignment.

5 BEAM STAY CLEAR

The vacuum chamber sizes are determined in each element taking the maximum between :

1. injected beam + 2 rms corrected CO
2. circulating beam at 2.5 GeV + 2 rms uncorrected CO
3. beam displacement at extraction

The beam stay clear of each elements are then :

element	horizontal	vertical
dipole	0.060 m	0.024 m
quadrupole	0.070 m	0.028 m
sextupole	0.070 m	0.026 m

6 EDDY CURRENT EFFECT, AND CROMATICITIES CORRECTION

With a repeating rate of 12 Hz, the induced field error from the Eddy current are strong. In the dipole, neglecting the corrugation, the main perturbation is a sextupolar field [5,6]. We present in figure 4 the variation of the chromaticity. Although we need to correct this induced chromaticity, the dynamic aperture remains large (figure5).

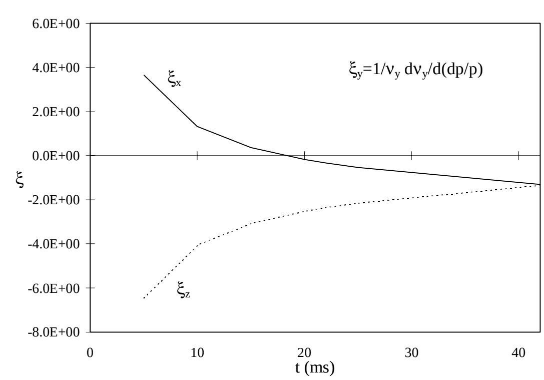

Figure 4 : Chromaticity induced by the Eddy current

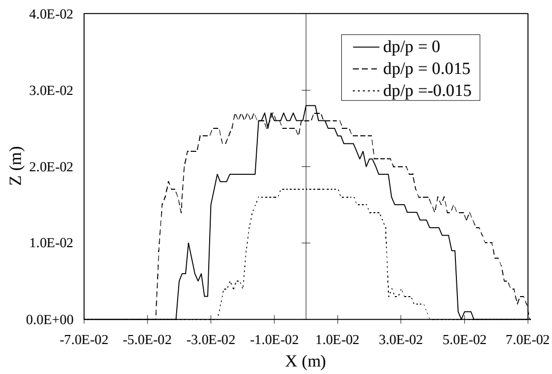

Figure 5 : Dynamic aperture at injection

7 SYSTEMATIC MUTIPOLAR TOLERANCES

Tolerances on systematic multipolar perturbations have been determined (table 4) to have the smallest dynamic aperture (figure 6) compatible with the injected beam size for particles having 1.5 % of energy spread [4].

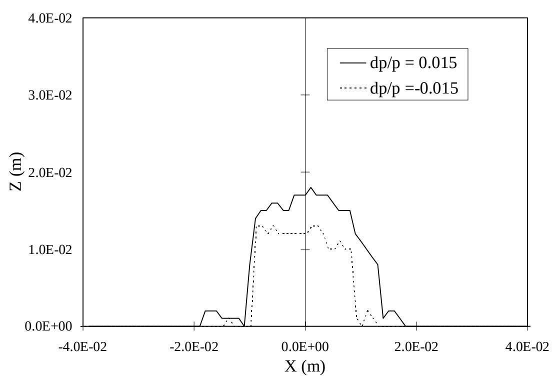

Figure 6 : Dynamic aperture including multipolar effects

Systematic multipolar tolerances for bending magnet	
dBl/Bl 6 poles at 0.03 m	$< 5\ 10^{-03}$
dBl/Bl 10 poles at 0.03 m	$< 1\ 10^{-03}$
dBl/Bl 14 poles at 0.03 m	$< 1\ 10^{-03}$
Systematic multipolar tolerance for quadrupole	
dGl/Gl 12 poles at 0.03 m	$< 1\ 10^{-02}$
dGl/Gl 20 poles at 0.03 m	$< 5\ 10^{-03}$
dGl/Gl 28 poles at 0.03 m	$< 5\ 10^{-03}$
Systematic multipolar tolerance for sextupole	
dBl/Bl 18 poles at 0.025 m	$< 1.5\ 10^{-03}$
dBl/Bl 30 poles at 0.025 m	$< 5\ 10^{-03}$

Table 2 : Multipolar tolerance

8 MAGNETIC STUDIES

The magnet optimization is nearly finished. We took into account several constraints : Antisaturation profiles, equal quality factors for the dipoles and quadrupoles, minimization of eddy current losses ... These precautions are necessary to ensure good quality magnets and especially a good tracking from 100 MeV and 2.5 GeV. The sextupoles are designed to correct chromaticities up to half of the ejection energy. For the moment they are DC powered, but they could be pulsed if necessary. The magnet characteristics are presented in the table 5.

	Dip.	QF/QD	Sext.
Number	24	20/20	24
Gap or bore ϕ (mm)	30	57	68
Strength $_{nom}$	1.006T	11 T/m	16 T/m^2
Length (m)	2.17	0.4	0.16
Good field re. (mm)	± 25	± 30	± 30
I_{max} AC part (A)	786	156	
I_{max} DC part (A)	786	156	18
U AC part (V)	7 000	1 700	
U DC part (V)	260	80	15
Homogeneity :			
- required	10^{-3}	$5\ 10^{-3}$	10^{-2}
- computed (2D)	$\pm 10^{-4}$	$5\ 10^{-3}$	10^{-2}
Reproducibility	10^{-3}	$5\ 10^{-3}$	10^{-2}
Quality factor	25.5	21.6	

Table 5 : Main characteristics of the booster magnets.

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